A MECHANISM FOR ORGANIC CORRELATION[1]

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The year 1909 is notable for its many historical associations. It is not only the fiftieth anniversary of the publication of "The Origin of Species," but it is also the centenary of the birth of Charles Darwin and of the publication of Lamarck's "Philosophie Zoologique." To the American its associations with Lincoln are precious memories. But it is not to these historical matters that I wish to refer. Science ever looks forward, not backward, and it is on certain modern aspects of the movements centering about the problem of evolution and especially on those connected with the name of Darwin that I wish to speak.

Although biologists have been familiar with Darwin's theory of natural selection for almost fifty years, it must be confessed that they are only at the threshold of the problem of evolution. That species have arisen by transmutation is now universally admitted, but how transmutation has been accomplished remains at present one of the unsolved riddles. The Lamarckian factors, though possible, must be set down as still unproved. Natural selection, so far as observation and experiment go, seems to play a real part in transmutation, but the extent of its application is still a matter of much uncertainty. Even the recently advanced mutation theory, on which hopes at one time ran high, is coming to assume at best a supplementary rôle. In fact it is evident that the most serious efforts of the past have failed of full accomplishment and it seems likely that the process of transformation is not exclusively dependent upon any single principle, but is of great complexity involving in all probability a consid-

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erable number of factors. Of these factors we are only beginning to get glimpses. I believe they will come into clearer view only as we progress in the solution of general biological problems. It is my intention to bring before you very briefly one of these lines of progress and to point out its possible bearing on the problem of evolution.

You are all doubtless familiar with the claim that Darwinism or natural selection is at best only a partial or insufficient factor in evolution. Its actual workings seem to be concerned with the elimination of only the most poorly adapted members of any stock; it is a process that is not closely enough adjusted to call forth those slight but constant differences which every systematist recognizes as the distinguishing marks of a species. To quote from a recent criticism:

> Every student of systematic zoology or botany has a keen realization . . . of the fact that a majority of the distinguishing characters which he recognizes in the various species . . . that come under his eye are of a sort that reveal to him no trace of particular utility.

For this reason it is believed that these characters could not have been produced through natural selection. I hope to show you, however, that we can make the admission implied in this quotation, to the effect that specific characters are not necessarily useful, and still be able to explain their occurrence and fixity through Darwinism.

A general outline of this proposition has already been given by Plate in his consideration of correlation. According to this author the development of a specific character of no special use may take place through correlation, that is, through that unknown law of growth by which an indifferent organ may be so bound up with or related to a useful organ that it, the indifferent organ, is perfected along with the useful organ as this latter is developed or specialized through selection. In this way it is conceivable that a specific character, even though useless, may arise at least indirectly through natural selection. It is to be noted that Plate's conception of the mechanism of correlation is not detailed; in fact, he

describes this principle as an unknown law of growth. It is to this aspect of the subject that I wish to direct your attention.

Only a superficial acquaintance with organisms is needed to make one familiar with many examples of correlation. A hairy integument is always associated with mammary glands; albinism in fur and skin is accompanied with a red color in the eye; and many other examples of correlated characters might be given. The question that we have to consider is the nature of the association in correlated characters and much light can be thrown upon this, I believe, by a study of the ductless glands.

The ductless glands such as the thyroid, the suprarenal bodies and the hypophysis of the brain were originally supposed to be functionless, but recent work has shown them not only to be functional but absolutely essential to the continuance of life. The removal of the suprarenal bodies from a mammal is invariably followed by death within a few hours and the loss of the hypophysis or the thyroid is also fatal though only after a somewhat longer interval. It is thus quite evident that these organs are of vital importance and that the continuance of life is dependent upon their presence. But they are not only necessary for life; they profoundly influence the form and structure of the organism in which they occur. This is best seen in the case of the thyroid. In extreme disease of this gland or after its removal in the higher mammals, the skin thickens and thus produces a misshapen aspect in the features and the extremities, there is a tendency to the loss of hair, and the nervous organs are so affected that the animal sinks into a condition of semi-idiocy (cretinism). Thus there are not only fundamental internal changes, but the external features such as a naturalist might use in describing a species are profoundly modified. Certain external features, then, in the normal animal are correlated with the state of the thyroid and, as disease and experiment show, they fluctu-

ate with the changes in the state of this gland. Our normal skin and features are thus dependent upon the integrity of this internal organ.

The mechanism of correlation between two such organs as the thyroid and the skin has already been somewhat worked out. It is natural to suspect that this correlation is nervous, for both thyroid and skin are supplied with an abundance of nerves coming from a common central organ. But the fact that the symptoms already described as the result of the removal of the thyroid can be checked and even made to disappear by grafting into the animal that has lost its thyroid, a part of a living gland from another animal, shows conclusively that the nervous system is not concerned. The further observation that animals devoid of thyroids may be kept in normal condition by injecting thyroid juice into them or even by feeding them with fresh thyroid glands from other animals, has suggested the idea that this gland produces a substance which makes its way into the blood and is thus carried to those parts of the body where it is needed. It is through this substance that the skin is influenced in that in the absence of this material the skin suffers serious change. The mechanism of correlation between the thyroid gland and the skin, then, consists in a substance produced by the gland and carried in the fluids of the body to various organs, including the skin, whose growth and appearance is thereby modified.

Similar observations have led to a like conclusion concerning the action of the suprarenal bodies and the hypophysis. These organs, like the thyroid, produce substances that make their way into the fluids of the body and influence its structure and action in so profound a way that they are absolutely essential to its continued existence. In the case of the suprarenal bodies the active substance has been isolated and is known as adrenalin. Since these internal secretions have the power of calling forth or exciting very marked changes in the body, they have been given the general name of hormones. It would,

however, probably be a mistake to regard the production of these hormones as limited to a few organs such as the thyroids, suprarenal bodies, etc. The most recent work in this field points to the conclusion that all active organs of the body, nerve centers, muscles, glands, etc., produce hormones which in the blood probably exert extensive influences on the parts with which they come in contact, and examples of this kind are being rapidly discovered. It was formerly supposed that the secretion of the pancreatic juice, which is poured into the small intestine when the partly digested food from the stomach reaches that organ, was dependent upon a nervous signal given to the pancreas from the intestine, but it is now well established, through the brilliant work of Bayliss and Starling, that the action of the acid food on the walls of the intestine produces a hormone, called secretin, which when carried in the blood to the pancreas will cause that organ to secrete. The evidence of this lies in the fact that when a small amount of secretin is injected directly into the blood stream of a mammal, the pancreas, whose nerve supply may have been cut off, will begin to secrete without the presence of food in the intestine. Still more remarkable is the correlation between the mammary glands and the embryo in mammals. It is well known that as the time for the birth of a mammal approaches, the mammary glands of the parent grow in size and structural changes appear preparatory to the secretion of milk. This correlation between the growth of the embryo and the growth of the mammary glands can not depend upon nervous coordination, for the nerves of the embryo have no connection with those of the maternal body. The correlation depends upon a substance, a hormone, produced in the body of the embryo and transmitted to the blood of the mother, whereupon it so influences the mammary glands as to start their growth. The evidence for this lies in the fact that if the extracted juice of a rabbit embryo is injected periodically into the circulation of a virgin female rabbit, her mammary glands can be in-

duced to take on the growth characteristic of the early stages of pregnancy though she is absolutely without young.

Another important set of bodily correlations are those that exist between the reproductive glands and the secondary sexual organs such as the comb, hackles and spurs of the common male fowl. It is well known that if the genital glands of a young male fowl are removed before it has attained maturity, it will fail to perfect its secondary sexual organs and the usual external evidences of maleness may be absent. But if, as Shattock and Seligmann have shown, a small piece of a male gland is grafted into a young castrated male the comb, hackles, and spurs may develop as in a normal bird. It is, therefore, highly probable that the reproductive glands, like the ductless glands, produce hormones by which the development of the secondary sexual organs is determined.

Not only are hormones produced in the adult body, but they are very probably formed during development. Such at least seems to be the condition in the correlated growth of the vertebrate eye and its lens. As is well known, the eyeball in the vertebrate is formed around an outgrowth from the brain; the lens is developed from the skin in such a position as to fit the forming ball. This interesting correlation in position between the external lens and the deep-seated eyeball has been made clear by Lewis who has shown that when the forming eyeball of a given species of frog is covered by grafting over it skin from the abdominal region of even another species of frog, this foreign abdominal skin will begin to form a lens in an appropriate position for the underlying eyeball. Apparently the eyeball gives out a substance, a hormone, that so influences the adjacent skin that, irrespective of its source within certain limits, it forms a lens. Thus embryonic correlations may also depend upon hormones.

These numerous examples show that many organs of the body produce hormones that profoundly affect the

form and structure of many other organs, external as well as internal. And further that these hormones are in some cases absolutely essential to the continuance of life. In short we must consider the interior of every organism as exhibiting an environment to which every organ probably contributes and by which every organ is more or less influenced. The hormones of this environment are the mechanisms of correlation and by means of them one organ influences another. It is no longer necessary to describe organic correlation as an unknown law of growth. It is the dependence of one organ on another through the hormones that the influencing organ produces.

Granting this condition, it follows that natural selection may well be conceived to modify an internal hormone-producing organ, if this organ is of vital significance, and incidentally thus to establish a new internal environment that would so influence the form and external configuration of a given organism that it would be called a new species and yet none of the new external features by which this organism would be described might show the least usefulness.